

INSTALLATION AND OPERATOIN OF SPRAGUE ELECTRO - DYNAMOMETER

BY

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ARMOUR INSTITUTE OF TECHNOLOGY

1914



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Installation and operation
of 100 horse power Sprague

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Installation and Operation of 100 Horse
Power Sprague Electro-Dynamometer,
Including Tests of 40 Horse Power
4 Cylinder Tee Head Teetor Motor
A THESIS

PRESENTED BY

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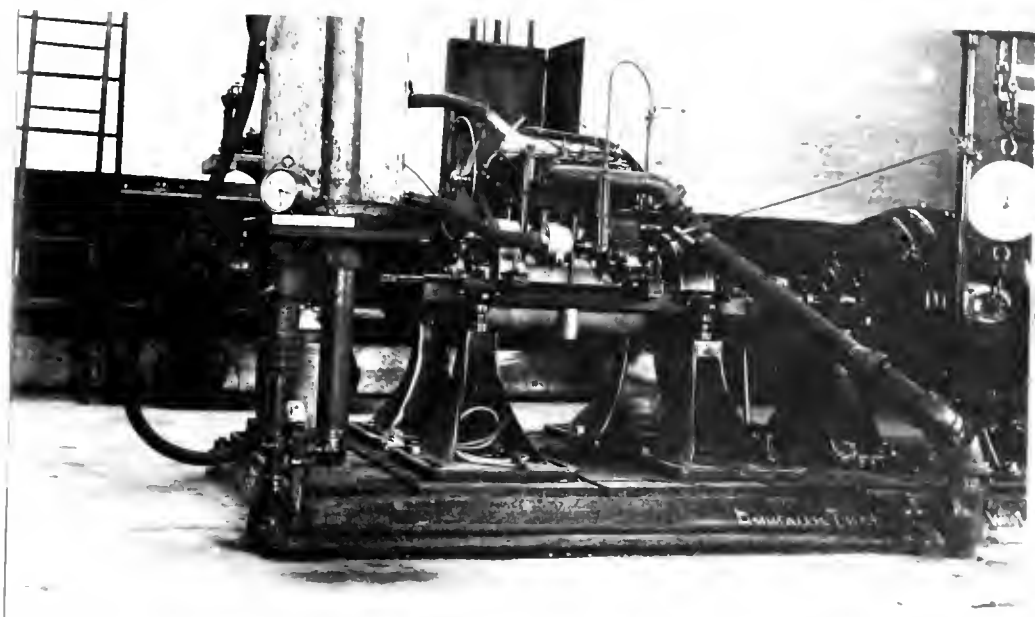
H. M. Raymond

L. C. Morin

PREFACE.

The recent developement of the high speed gasoline engine has made a demand for a better method of measuring the power output of these engines than has been possible by the use of the prony brake and water brake dynamometers. To meet this demand, the electrodyamometer has been put on the market. It is to show the adaptability of this apparatus to the testing of a high speed automobile engine that the authors of this paper will strive.

Included in this paper are tests on a four cylinder automobile to determine the comparative effect of using one and two sparks to ignite the mixture.



ENGINE FROM MAGNETO SIDE.

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CHAPTER I.

DYNAMOMETERS IN GENERAL.

The testing of high speed gasoline engines requires a means of absorbing the power developed which has a wide range of speed of operation and will maintain a constant torque at each speed. It should also allow the torque to drop off in case the speed was decreased due to the missing of an explosion. If such an apparatus also easily and swiftly controlled and required no calibration for different conditions of testing, then the maximum of efficiency in testing could be realized.

The prony brake, which is the best known means of absorbing the power developed by an engine, has the objection of its excessive heating and liability to seize at high speeds. It is also practically impossible to hold a constant torque for any length of time with this brake.

The power developed by the engine is resisted by the friction between the rubbing surfaces of the brake. Work is done in overcoming this friction and dissipated to the air as heat. The force acting to overcome the friction is the torque of the engine.

Since the friction is constant irrespective of the speed, the torque is constant for any variation in speed. This means that in using the prony brake in testing a high speed

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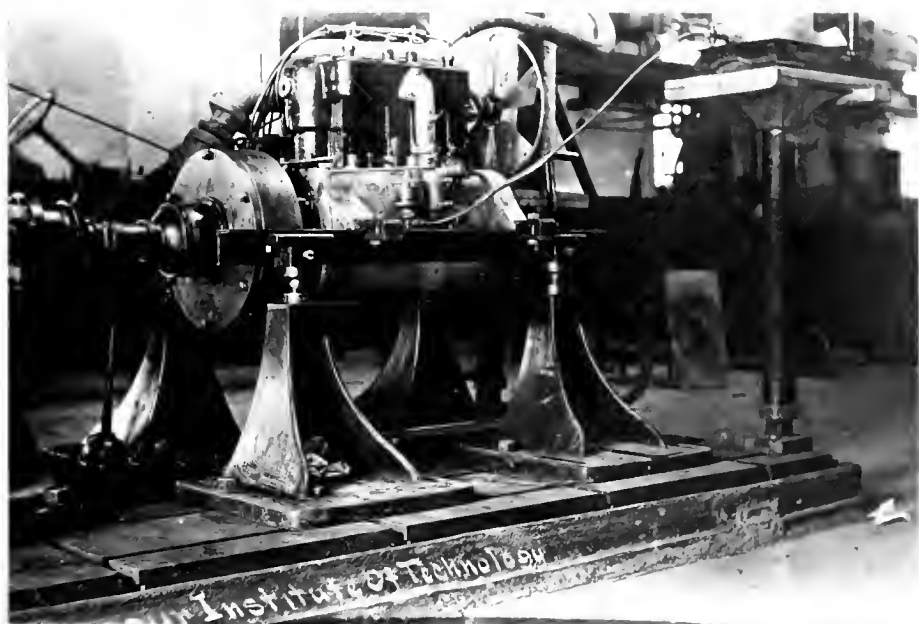
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Since the friction is constant irrespective of the speed, the torque is constant for any variation in speed. This means that in using the prony brake in testing a high speed

gasoline engine the engine would probable be stopped if the speed momentarily fell off due to the missing of an explosion.

The water brake dynamometer operates on the same principle as the prony brake. In it the friction surfaces are separated by a thin film of water. It is the friction of the blades running through the water that absorbs the power. As with the prony brake, the friction force or torque remains constant for variations of speed and hence it has the same objection as the prony brake to its use in testing high speed gasoline engines.

Fan dynamometers would be ideal for use in testing work were it not for the fact that they



ENGINE FROM CARBUERATOR SIDE.

require calibration for every change in atmospheric conditions. With this type of dynamometer, the torque falls off as the square of the speed which makes it especially adapted to gasoline engine work. Because of its need of calibration for every condition of operation and because of its bulk, this type of dynamometer has not been used to any extent for this type of work.

The electrical method of determining the output of the engine has proven unsatisfactory because of the many sources of error entering into the readings and because of the labor involved in conducting the test and in making the computations.

CHAPTER II.

THE ELECTRO-DYNAMOMETER.

The electro-dynamometer consists of an electric generator whose field is balanced and free to revolve within small limits about two roller bearings. The armature of the generator is direct connected to the crankshaft of the engine. As the armature revolves in the magnetic field it tends to draw the field about with it. The amount of this pull on the field can be measured by means of a system of levers transmitting the force to a scale beam. The electrical power

may be dissipated as heat by a rheostat or made to do useful work.

As with the prony brake, the power of the engine is used to overcome a resistance at a known speed. Hence the prony brake formula for horse power is applicable to the electro-dynamometer. The resistance overcome in the dynamometer is the resistance to the cutting of lines of magnetic force by the armature and the windage of the armature which is negligible. Hence the torque is the force tending to rotate the field and its lever arm is the distance out from the center to the point where the torque is measured. Then the horse power absorbed by the dynamometer will be some constant (K) times the product of the torque (L) in pounds by the speed (N) in R.P.M.

With the electro-dynamometer the torque varies as the speed. This may be shown as follows:

The electrical horsepower of a perfect generator would be equal to the power expended on the machine, or the input would be equal to the output in other words.

Using the same notations, the H.P. input is $K L N$.

Letting (E) represent the voltage and (I) the amperes output of such a machine, the horsepower output would be $1.34 E I$.

Now $K L N = 1.34 E I$.

From the equation of an electric circuit $I = E / R$, where (R) is the resistance which would be constant for this case and so may

be combined with the other constants into the symbol (C).

$$\text{Then } C L N = E^2$$

The equation for the E.M.F. of a generator is as follows :

$$E = 2 \pi S \frac{N}{60} 10^{-8}.$$

The product of the members on the right hand side of the equation is a constant (A) times the variable (N) for the case under consideration.

$$\text{Therefore } E = A N .$$

Substituting this value in the horsepower equation:

$$C L N = (A N)^2 .$$

Solving for (L) :

$$L = \frac{A^2}{C} N .$$

Which demonstrates the proposition that the torque varies as the speed with the electro-dynamometer.

CHAPTER III.

DESCRIPTION & OPERATION OF THE SPRAGUE ELECTRO-DYNAMOMETER.

The Sprague electro-dynamometer, as installed at Armour Institute of Technology, consists of a 100 horsepower direct current inter pole generator mounted on a cast iron bed plate.

The pull on the field or torque is taken from knife edges screwed to the frame of the generator and transmitted through a draw-bar and spring balance scales to a set of Chatillion scales. The length of the arm is made equal to 1.315 feet so that the torque times the R.P.M. divided by 4000 gives the horsepower developed.

Ways are cast in the bed plate for holding down the adjustable motor stands. Provision is made for moving these stands in any direction on the plate and raising and lowering the top rails to accomodate any engine.

The engine can be lined up with the armature shaft and a flexible coupling be inserted between the two.

In order to maintain a steady field flux that will not vary with the speed, the field is separately excited.

The switch-board is mounted on pipe stands located within reach of the scale beam. It contains the control switches, field rheostat, circuit breaker, ammeter and voltmeter, and the voltmeter for the electro-tachometer. The accompany-

ing drawing shows the electrical connections of the apparatus.

The following instructions for operating were sent out with the machine by the Sprague Works.

"INSTRUCTIONS
FOR OPERATING THE SPRAGUE
ELECTRO-DYNAMOMETER.

"Preliminary Adjustment.

"The dynamometer should first be balanced at standstill and before connecting it to the engine to be tested. Care should be taken that the incoming leads to the dynamometer frame do not exert a pull which interferes with the pull of the dynamometer frame on the beam scale. When a balance has been obtained with the

beam scale reading "Zero", connect the engine to be tested.

"Starting".

"Leave all the single pole switches open. See that the field rheostat is turned as far as it will go to the full field position. Close the field switch and be sure there is current in the field circuit. Trip the circuit breaker and put both interlocking switches to the right. Close the single pole switches in the upper row one at a time. The machine should start after two or three switches have been closed.

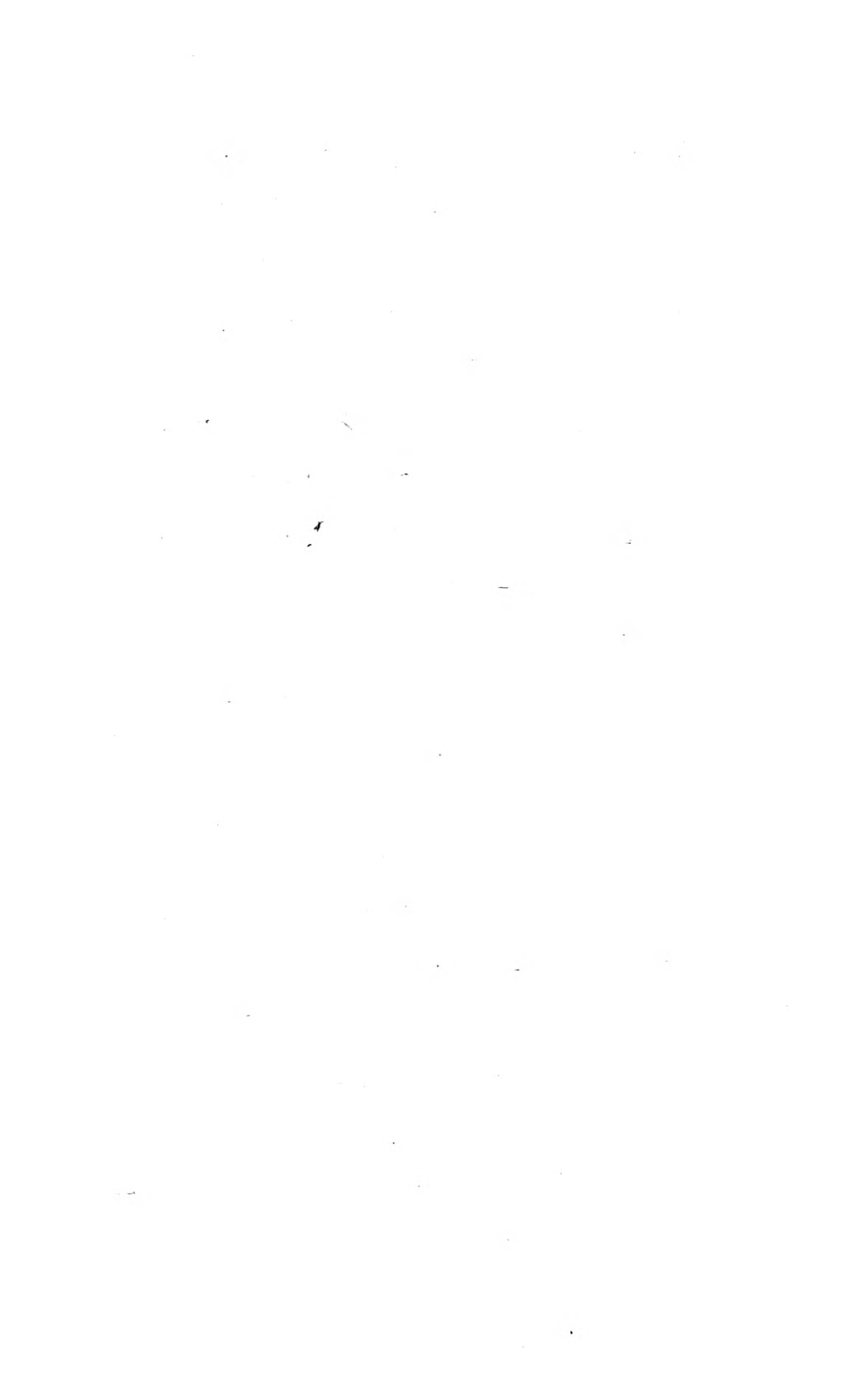
"Operation as Motor".

"If it be desired to increase the speed in order to take friction tests at higher speeds than that of starting, continue closing the switches

In the top row one at a time. When all the top switches are in close the circuit breaker which short circuits the resistances. If speed is to be still further increased, open all the single pole switches and slowly turn the field rheostat handle so as to weaken the field. PRECAUTION - Do not weaken the field before the circuit breaker has been closed and all the single pole switches opened.

"Operating as Generator.

"Before opening the dynamometer as a generator see that the field rheostat is turned to the full field position and two or three switches in the top row closed. When the engine to be tested has begun to run under its own power throw the lower transfer switch to the left. The load is now



increased by closing the switches in the top row and at the same time supplying more power to the machine being tested. Variation in speed is obtained by the field rheostat.

"To load the dynamometer at speeds below one half of normal speed as stamped on the dynamometer name-plate, close three or four switches in the lower row leaving the switches in the top row closed, and throw the upper half of the transfer switch to the left. The load may now be increased by closing the switches in the lower row one at a time.

"Care should be taken to manipulate the load switches and field rheostat so that the current does not exceed three hundred amperes and the voltage on high speed load does not exceed 250 volts continuous

or 300 volts for five minutes. In increasing the load when running at half the normal speed if the current rises over three hundred amperes, strengthen the field and open a few switches. Do not allow the voltage when running at half of normal speed to go much above 125 volts".

In determining the torque necessary to drive the engine, a correction must be made to the reading taken. This correction is found by driving the motor free at the speed at which the engine torque is taken. The correction is subtracted from the total torque and is made to correct for windage of the armature.

CHAPTER IV.

ENGINE & EQUIPMENT USED.

The engine tested was a four cylinder, four cycle, 4 1/2 " x 5 " "T" head Teetor automobile motor. The cylinders are cast en-block and a three bearing crank shaft is used. Lubrication is by the splash system to the pistons and connecting rods and by a forced system to the half-time gears and main bearings.

A Bosch Two Spark magneto and the centrifugal circulating pump are driven from a jack shaft geared through the half time gear operating the exhaust camshaft.

The fan is belt driven from a pulley on the overhanging end of the jackshaft.

A spark indicator was fitted up and operated by this shaft. It consisted of an insulated plate graduated in degrees and fixed by a bracket to the crankcase. A pointer was fixed on the cap screw holding the fan driving pulley in place. This pointer revolved about with the pulley which was driven at crank shaft speed. When the pointer was set in phase with the crank of cylinder No. 1 , the degrees at which the various events took place could be read on the insulated plate. To determine the point at which ignition took place, the high tension lead from the spark plug was

connected to the insulated plate and the position at which the spark jumped between the pointer and the plate read.

A Stromberg Model "A-2" carburetor was used throughout the tests. The water jacket was not connected however as the temperature at that point was deemed sufficient. In the adjustment of the carburetor, no attempt was made to obtain the most economical mixture but rather it was set as low as possible consistent with smooth running and flexibility.

A water meter in the cooling water intake had to be taken out because of the resistance it offered to the flow of water and its liability to stick at any time. In determining the water pumped, a calibration of the



Centrifugal pump was made. This should give results in keeping with the accuracy of the other variables.

The gasoline used was weighed from a small gasoline tank resting on a set of small platform scales.

A continuous speed counter was geared from the generator shaft. The electric tachometer was also driven from this train of gears.

A Manograph or optical gas engine indicator was used in obtaining some of the data. It was driven off the spark indicator pointer.

Illumination was furnished by a small arc light focused on the eye-piece.

It was designed and manufactured by J. Carpentier of Paris, France.



CHAPTER V.

ENGINE TESTS.

Three tests were made on the engine. Test No. 1 was made April 3, and Tests Nos. 2 & 3 were made April 7, 1914.

Test No. 1 was made with a wide open throttle at speeds increasing by intervals of 100 R.P.M. from 300 to 1600 R.P.M. Two runs were made at each speed, those designated "A" being made with two sparks, and those designated "B" being made with one spark. In setting the spark position, the engine was first loaded to give the approximate speed desired

then the position which gave the highest speed with two sparks determined with the aid of a hand tachometer. This position was not changed for the "B" run with one spark.

Test No. 2 was made with a wide open throttle at two speeds only, namely at approximately 1700 and 1800 R.P.M. Before making these two runs, the carbon was removed by an injection of kerosene in the cylinders. It was originally intended to include the results of this test in Test No. 1 but this was not done because of the marked improvement in the operation of the engine due to cleaning out the carbon.

Test No. 3 was made with a wide open throttle at speeds increasing

by intervals of 200 R.P.M. from 300 to 1700 R.P.M. As in Tests Nos. 2 & 3 two runs were made at each speed. However, in this test the spark position was changed to give the most power with the one spark as with the two.

The speed in these tests was determined by observing the time required by the engine to make an even number of hundreds of revolutions. Two such times were taken for each "A" and "B" run and the average used to determine the correct R.P.M.

The weight of gasoline was determined in much the same way, the time being taken for a definite number of tenths of a pound of gasoline to leave the tank. Two readings were also made for each "A" and "B"

run.

The method used in figuring the tests can best be shown by an actual computation. Run No. 4 A of Test No. 1 will be carried through as a sample calculation.

The log sheet shows that the average time required for 800 revolutions of the engine was 79.4 sec.

$$\begin{aligned}\text{Then R.P.M.} &= 800 \times 60 / 79.4 \\ &= 605 \text{ R.P.M.}\end{aligned}$$

The average time required for the engine to use 0.2 lb. gasoline was 44.5 seconds. Then the lbs. of gasoline per hour would be

$$0.2 \times 60 \times 60 / 44.5 = 16.15 \#.$$

The torque was 133.25 lbs which gives a horsepower developed of

$$133.25 \times 605 / 4000 = 20.15 .$$

The torque in lbs.ft. is

equal to the torque times the length of the arm in feet which gives

$$133.25 \times 1.315 = 175.2 \text{ lbs. ft.}$$

The friction horsepower as taken from the friction horsepower curve is equal to 2.55 H.P.

The Indicated horsepower then is the sum of the developed or brake horsepower and the friction horsepower which gives $2.55 + 20.15 = 22.70 \text{ B.H.P.}$

The gasoline consumption per B.H.P. hour is $16.15 / 20.15 = 0.803 \#.$

The gasoline consumption per I.H.P. hour is $16.15 / 22.7 = 0.712 \#.$

The density of the gasoline in degrees Baume was found to be 58.5 . From the equation for the low heating value of gasoline namely:

$$\text{B.T.U.} / \text{lb.} = 17030 + 40(B - 10).$$

in which (B) is the Baume reading, the heating value of the gasoline was

found to be 18970 B.T.U. per lb.

Then the total heat supplied
per I.H.P. hour would be

$$18790 \times 0.712 = 13500 \text{ B.T.U.}$$

and the total heat supplied
per B.H.P. hour would be

$$18790 \times 0.803 = 15230 \text{ B.T.U.}$$

Now the heat equivalent of
one horsepower is 2546 B.T.U. per hr.

Then the percent of the total heat
which is utilized as B.H.P. would

$$\text{be } (2546 / 15230) \times 100 = 16.7 \%$$

and the percent utilized as I.H.P.

$$\text{is } (2546 / 13500) \times 100 = 18.9 \%$$

From the calibration curve
of the pump we find that it circulates 44 lbs. of water per minute.
This times sixty and divided by the
I.H.P. of the engine gives the lbs.
of water circulated per I.H.P. hour.

This we find to be

$$44 \times 60 / 22.7 = 116.5 \text{ lbs.}$$

The temperature rise of the cooling water was 54 degrees Fahrenheit.

Hence the heat lost to the cooling water is

$$54 \times 116.5 = 6290 \text{ B.T.U.}$$

The percent heat lost to the cooling water is

$$(6290 / 13500) \times 100 = 46.5 \%$$

Of the total heat supplied 18.9 % has been accounted for as I.H.P. and 46.5 % as water jacket loss making a total of 65.4 % of the heat accounted for. The remaining 34.6 % represents heat lost in the exhaust and to radiation.

Tests No. 2 & 3 were figured in the same way with the exception of the fact that no heat balance was made for these two tests.

CHAPTER VI.

DISCUSSION OF RESULTS FROM ENGINE TESTS .

A comparison of the results obtained in using two sparks instead of one shows a marked improvement in economy and an increased horsepower in favor of the two spark system of ignition. The curves taken from Test No. 1 and Test No. 3 show these points up conclusively.

The curves from Test No. 3 are more reliable as a source of comparison than those from Test No. 1, because the engine was operated at its most efficient point of ignition for both the "A" and "B" runs in

Test No. 3 whereas the point of most efficient ignition was determined only for the "A" run in Test No. 1.

A study of the log sheet in Test No. 3 reveals the fact that the ignition is advanced just twice as far for one spark as for two. This advancing of the point of ignition with one spark in Test No. 3 serves to bring the horsepower curves with one and two sparks closer together than in Test No. 1.

The best economy of the engine is seen to be at about 750 R.P.M. where it is developing about 25 horsepower on a gasoline consumption of approximately 0.7 lbs. of gasoline per horsepower hour.

The heat balance sheet and

Heat Loss Distribution curves for Test No. 1 are of interest in tracing the thermal action of the engine. From the curves and data worked out the following relations seem to hold:

The percent of total heat utilized as preforming work within the engine increases as the speed increases.

The percent of total heat lost to the water jackets decreases as the speed decreases.

The percent of total heat lost in the exhaust and to radiation increases as the speed increases.

CHAPTER VII.

DATA SHEETS & CURVES.

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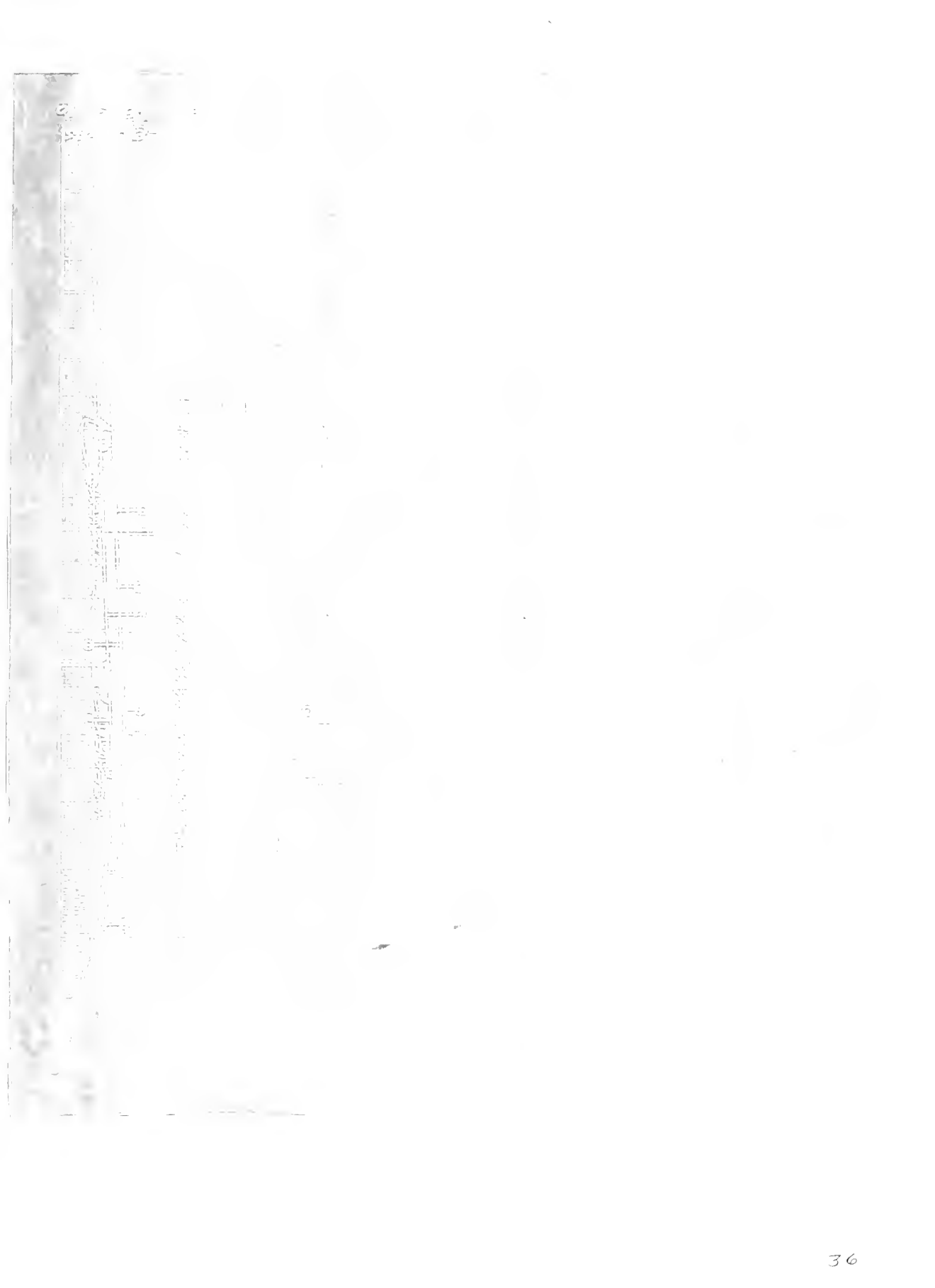
CALIBRATION OF CIRCULATING PUMP

NO.	1ST TIME.	2ND TIME.	AVER. TIME.	WT. IN PAIL.	#/MIN.	R.P.M.
1	21.6	300	21.8	10	28.2	400
2	17.3	18.0	17.65	10	34.0	500
3	14.0	10.2	15.6	10	38.5	600
4	23.2	22.8	23.0	20	52.2	700
5	19.0	19.5	19.25	20	62.4	800
6	17.4	17.8	17.6	30	64.1	900
7	23.5	23.4	23.45	30	76.6	1000
8	21.4	23.0	22.2	30	81.3	1100
9	21.2	21.2	21.2	30	85.4	1200
10	19.6	19.4	19.5	30	92.5	1300
11	17.5	18.2	17.85	30	99.0	1400
12	18.0	18.0	18.0	30	100.0	1500
13	18.0	17.0	17.5	30	101.5	1600
14	54.2	54.0	54.1	100	110.5	1700

RESULTS - TEST NR 1

RUN		RPM	TORQUE		Horse Power			Efficiency	
			SCALE	LB-FT	SHR	WGT	HP	TOTAL	NET
1	A	304	127.3	167.5	3.57	15	10.16	8.7	1.46
	B	297.5	122.7	161	3.08	14.5	10.58	9.25	1.33
2	A	418	131.5	175	4.55	15	15.74	13.5	2.24
	B	392	126.5	166.5	3.74	14.5	14.3	12.45	1.89
3	A	517	132.5	174	5.45	16	18.7	16.10	2.60
	B	492	127.0	167	4.56	15.5	17.2	14.65	2.11
4	A	605	134.5	175.2	6.05	16.5	22.70	19.15	3.55
	B	596	129.5	170.5	5.23	15.5	21.40	18.25	3.15
5	A	740	129.5	169	7.40	17	27.2	23.5	3.70
	B	728	126.5	166	6.40	16.5	26.3	22.75	3.55
6	A	834	132.0	178.0	8.15	17.5	32.05	27.5	4.55
	B	820	128.5	169	7.15	17	30.7	26.5	4.20
7	A	930	132.5	174	9.30	17.5	38.5	33.5	5.00
	B	896	129.5	170.5	8.25	17	36.75	32.5	4.25
8	A	1012	131	175	10.12	18	46.7	40.5	6.20
	B	974	130.5	171	9.15	17.5	45.05	39.5	5.60
9	A	1131	128.5	170.5	11.31	18.5	55.2	48.5	6.75
	B	1098	126.5	166	10.14	18	53.4	47.5	6.65
10	A	1205	126.5	155	12.05	19	65.4	57	8.05
	B	1152	124.0	151	10.45	18.5	61.5	53.0	7.45
11	A	1342	108.5	145	13.42	19	74.0	67	6.70
	B	1286	107.0	142.5	12.0	18.5	72.0	65.5	6.45
12	A	1425	103	135.7	14.25	19.5	80.5	74.5	6.00
	B	1385	100	131.5	12.85	19	78.5	72.5	5.70
13	A	1500	100	131.5	14.0	20	80.7	75.2	5.50
	B	1470	92.5	123	13.75	19.5	78.5	73.5	5.25
14	A	1625	96.5	115	16.25	20.5	87.0	80	6.25
	B	1578	87.0	107.5	14.45	20	84.5	78.5	5.65

14 A WITH 2.5 P LBS - B WITH 1.5 P LBS





RESULTS-TEST No 2.

RUN		R.P.M.	TORQUE		HORSE POWER			GASOLINE	
			SCALE	LBS. FT.	B.H.P.	FRICT	I.H.P.	TOTAL	*/B.H.P.
1	A	1750	90.0	118.2	39.3	11.0	50.3	30.0	.762
	B	1715	87.5	115	37.5	10.8	48.3	30.0	.800
2	A	1860	79.5	104.5	37.0	11.9	48.9	31.3	.846
	B	1790	78.5	103.2	35.1	11.5	46.6	30.6	.873

RUN 'A' WITH 2 SPARKS - 'B' WITH ONE SPARK.

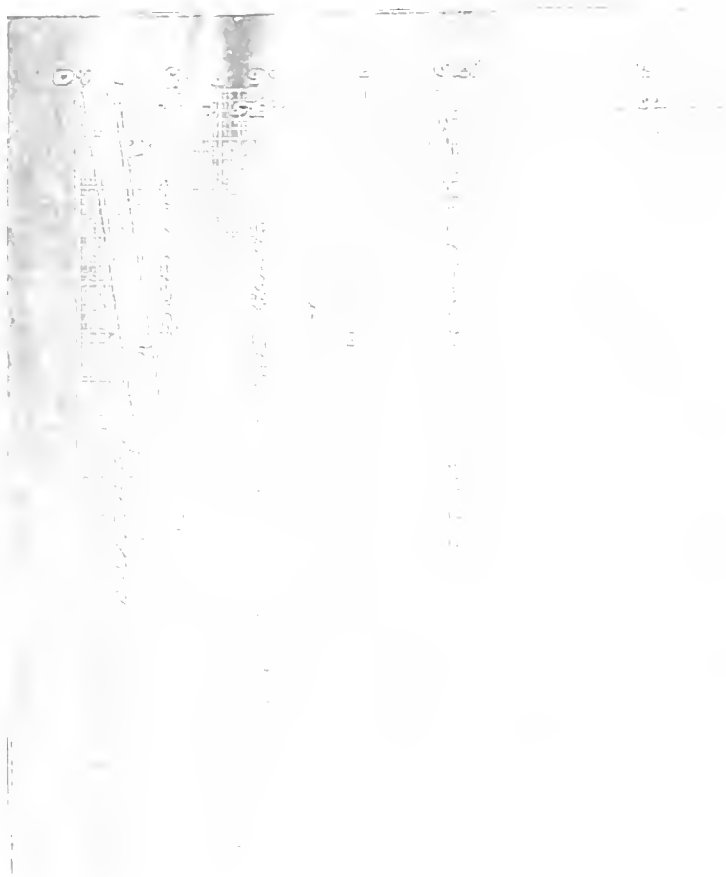
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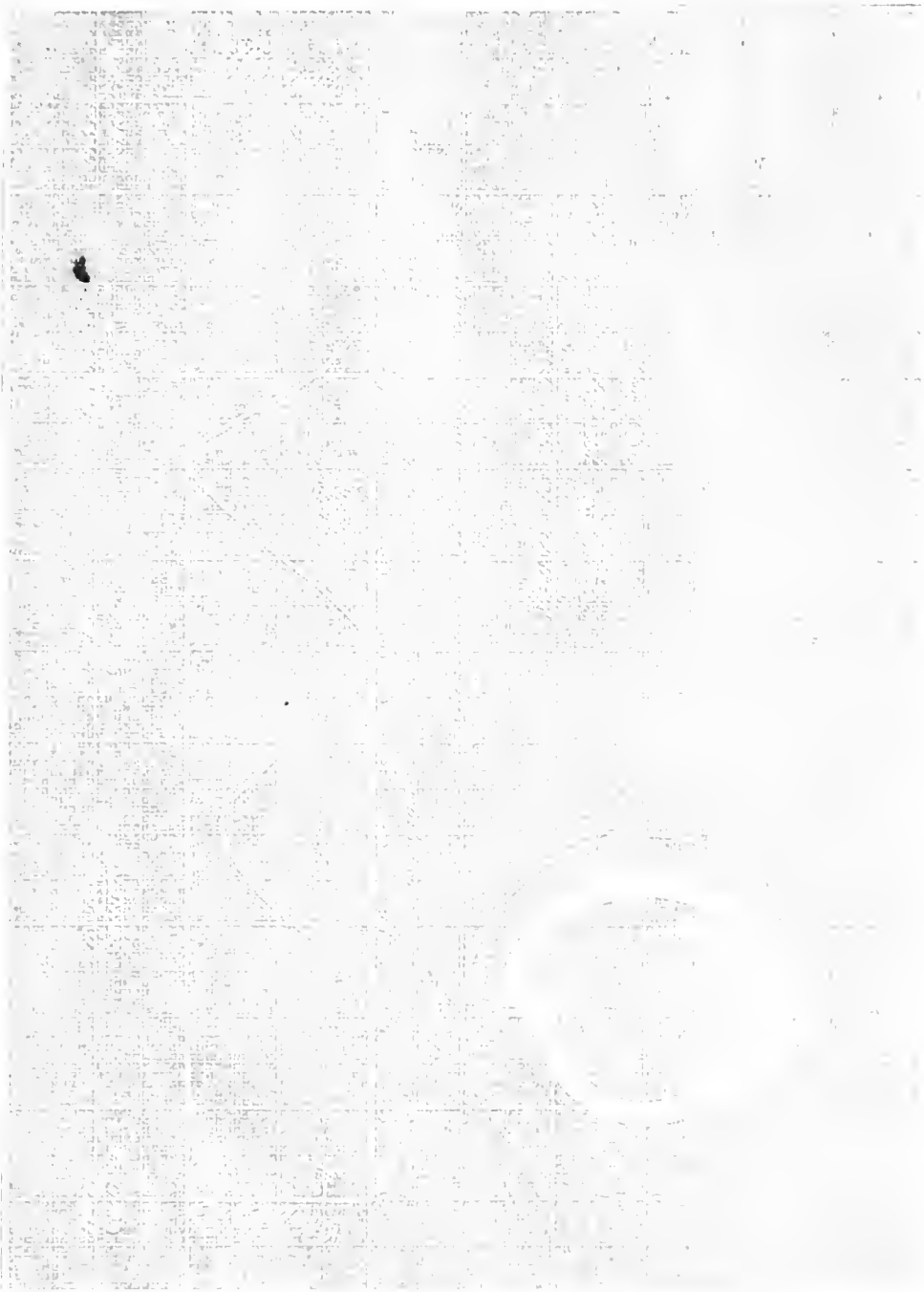


RESULTS TEST NO 3

RUN		RPM	TORQUE		HORSE POWER			GASOLINE	
			SCALE	LEVER	B.H.P.	FRIC.	P.H.P.	TOTAL	W/COND.
1	A	318	130.3	171.2	10.35	1.57	11.87	9.74	.94
	B								
2	A	498	140.5	184.5	17.5	2.02	19.52	12.85	1.35
	B	468	132.	175.5	15.45	1.95	17.40	12.62	1.18
3	A	719	136	179	24.42	3.22	27.64	17.13	1.02
	B	693	132.8	174.7	23.02	3.08	26.1	16.75	1.28
4	A	908	137	180.5	31.1	4.5	35.6	20.85	1.31
	B	869	132.8	174.7	28.8	4.2	33.0	19.72	1.85
5	A	1065	127.5	168	33.9	5.8	39.7	25.1	1.4
	B	1028	120.5	158.5	30.9	5.5	36.4	23.6	1.7
6	A	1253	111.5	146.7	34.9	7.2	42.1	28.6	1.91
	B	1236	110.0	145.0	33.9	7.1	41.0	28.2	1.32
7	A	1442	98.5	129.5	35.6	8.7	44.3	30.6	1.86
	B	1422	87.5	128.0	34.7	8.6	43.3	30.3	1.73
8	A	1700	88.3	116.0	37.5	10.8	48.3	35.1	1.12
	B	1650	84	110.5	34.6	10.4	45.0	33.1	1.57

RUN 'A' WITH 2 SPARKS- 'B' WITH 1 SPARK





CHAPTER VIII.

MANOGRAPH CARDS.

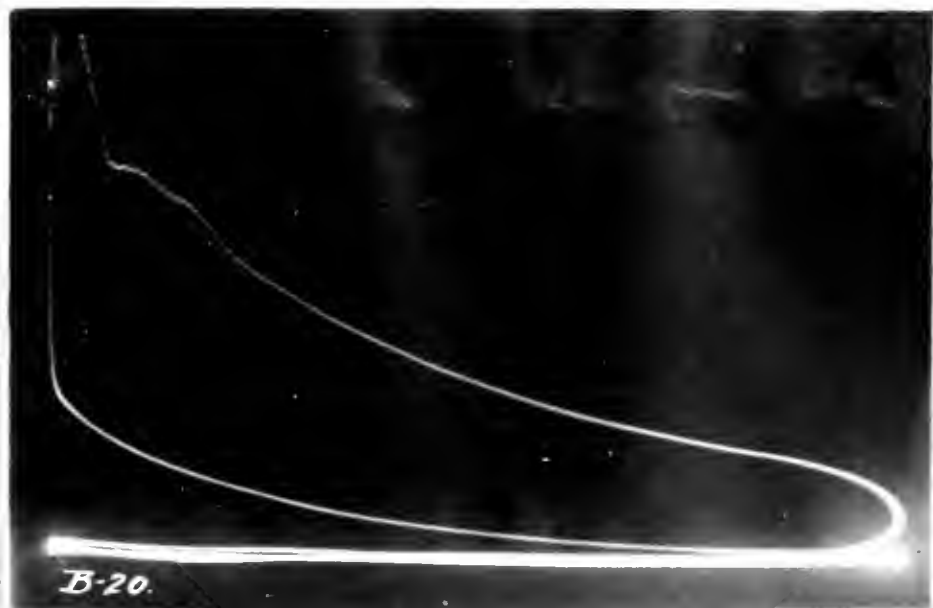
Considerable difficulty was met in the use of the manograph in obtaining a straight atmospheric line. This was found to be due to an inherent defect in the design of the oscillating mechanism. Before taking the cards herewith presented, this error was largely overcome by changing the design of this mechanism so that a straight line was possible.

The disks used were calibrated with a corrected pressure gauge on air pressure.

A curve was plotted to show the variation of the compression pressure with the speed.

Card No. 1 .

Full card	Disk "B".
Speed	500 R.P.M.
Torque	171 ft.lb.
Throttle	Wide open.
1 spark	30 deg. early.

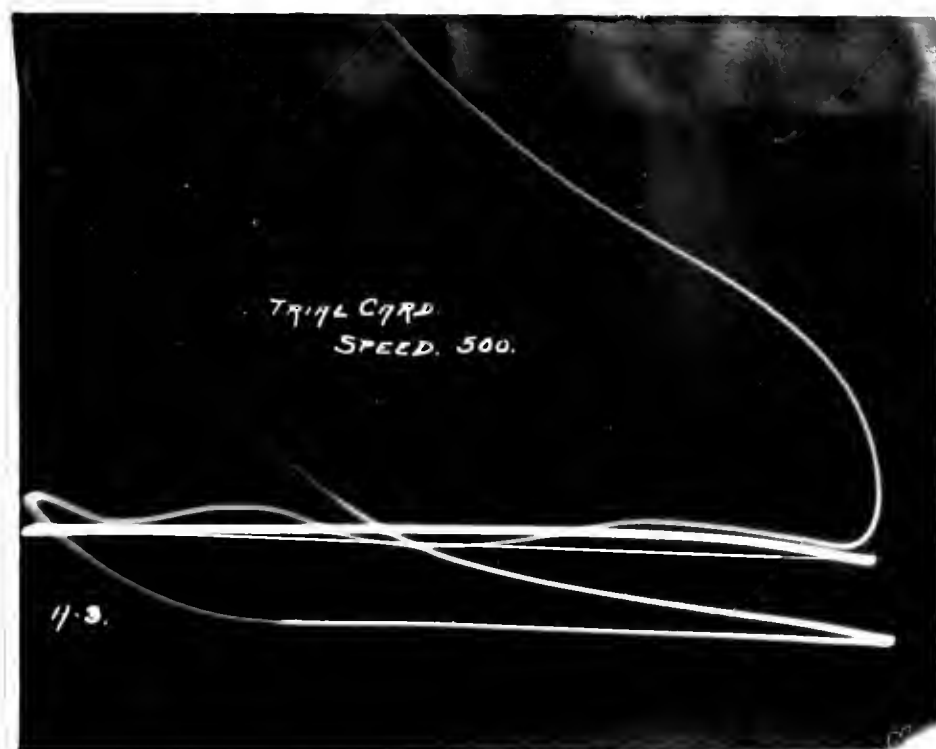


Card No. 1 .

Card No. 2 .

Stop motion card	Disk "A".
Speed	500 R.P.M.
Torque	63 lbs.ft.
Throttle	partly closed.
1 spark	20 deg. early.

Note lateness with which
compression line crosses atmospheric
line showing small volume of gas in
cylinder and low compression pressure.



Card No. 2 .

Card No. 3 .

Full card	Disk "B".
Speed	750 R.P.M.
Torque	167 lbs.ft.
Throttle	Wide open.
1 spark	30 deg. early.



Card No. 3 .

Card No. 2 .

Card No. 4 .

Full card	Disk "B".
Speed	1000 R.P.M.
Torque	172 lbs.ft.
Throttle	Wide open.
1 spark	30 deg. early.

Note slow burning mixture with one spark as compared to swift burning mixture with two sparks as shown in Card No. 5 .



Card No. 4 .

Card No. 5 .

Full card	Disk "B".
Speed	1000 R.P.M.
Torque	176 lbs.ft.
Throttle	Wide open.
2 spark	30 deg. early.

Note quick burning mixture as compared with that shown by Card No. 4 . This shows the effect on the rapidity of flame propogation produced by using two sparks instead of one to ignite the mixture.

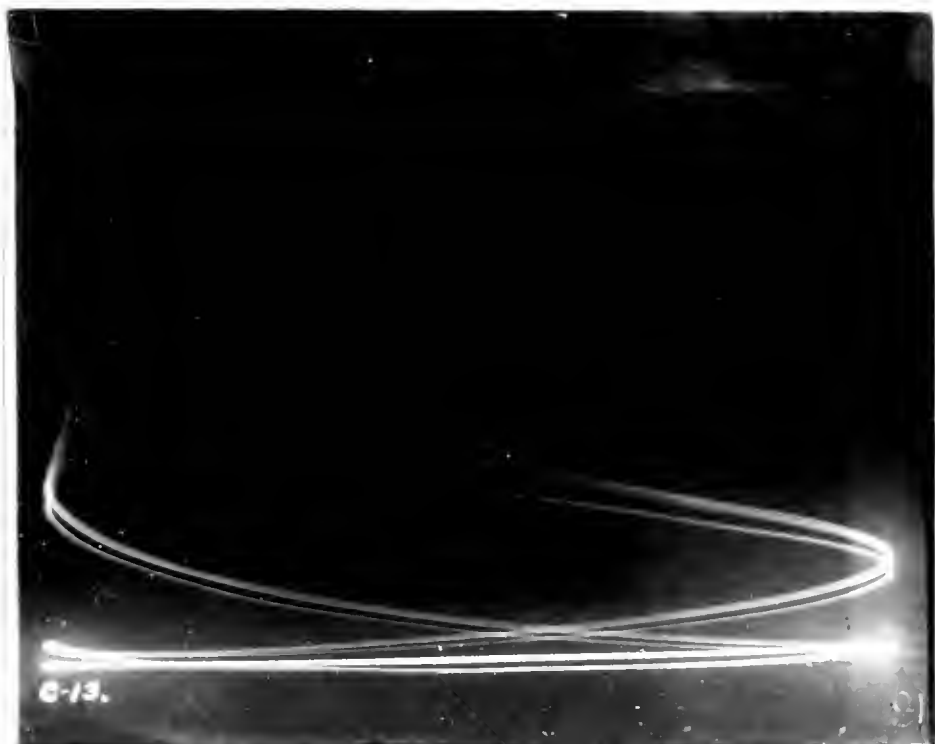


Card No. 5 .

Card No. 6 .

Full card	Disk "B".
Speed	1500 R.P.M.
Torque	103 lbs.ft.
Throttle	Wide open.
1 spark	16 deg. early.

Note double exposure
of plate giving two complete cycles
instead of one.



Card No. 6 .

Card No. 7 .

Calibration of Disk "B" with air.

Data

Point	Gauge	Correct
0	0	0
1	15	13
2	20	18
3	30	27
4	40	37
5	50	45
6	60	55
7	70	67
8	80	77.5
9	100	96
10	120	115
11	140	134
12	160	150
13	180	165
14	200	182
15	220	200
16	240	218
17	260	238

Pressures in lbs./ sq.in.



Card No. 7 .

Card No. 8 .

Calibration of Disk "A" with Air.

Data

Point	Gauge	Correct
0	0	0
1	10	10
2	15	13
3	20	18
4	25	22.5
6	30	27.5
7	40	37
8	50	45
9	60	55
10	70	66.75
11	80	77.5

Pressures in lbs./ sq.in.



Card No. 8 .

Card No. 9 .

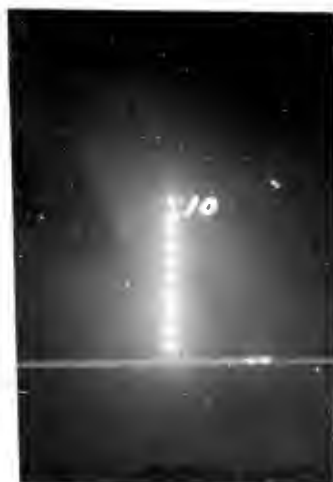
Calibration of Disk "A" with Air.

Data

Point	Inches Hg.	Gauge
0	2.04	1
2	4.08	2
3	6.12	3
4	8.16	4
5	10.20	5
6	12.24	6
7	14.28	7
8	16.32	8
9	18.36	9
10	20.4	10

Gauge pressures in Lbs./ sq.in.

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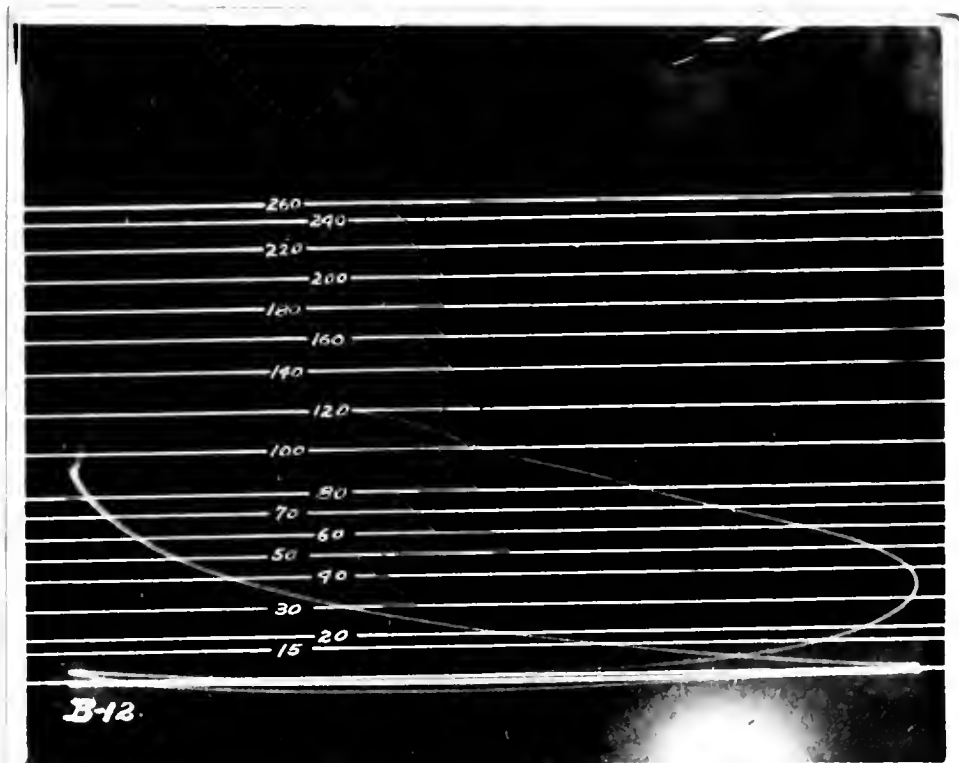


Card No. 9 .

Card No. 10 .

Full card	Disk "B".
Speed	900 R.P.M.
Torque	150 lbs.ft.
Throttle	Wide open.
1 spark	20 deg. early.

Pressure have been laid
off accurately from data taken from
Card No. 7 .

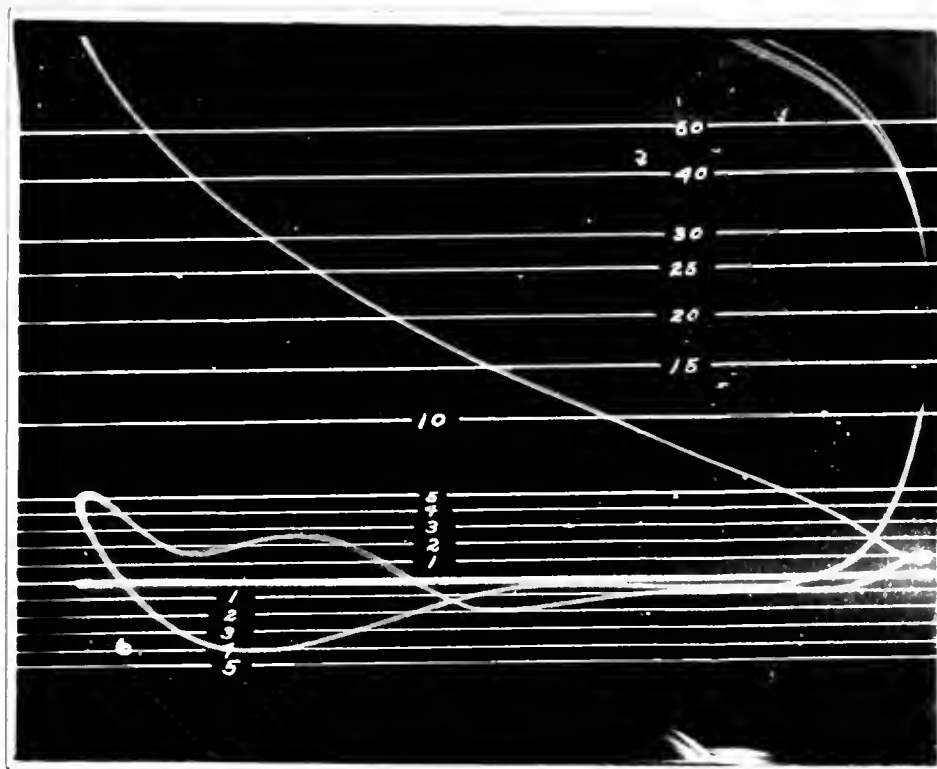


Card No. 10 .

Card No. 11 .

Stop motion card	Disk "A".
Speed	518 R.P.M.
Torque	181 lbs.ft.
Throttle	Wide open.
2 sparks	10 deg.early.

Note full charge of gas in the cylinder as compared with the charge shown in Card No. 2 . This shows the effect of throttling on the events of the cycle. The horizontal lines are the pressures in lbs. per sq. inch as found from Cards 7 and 8.

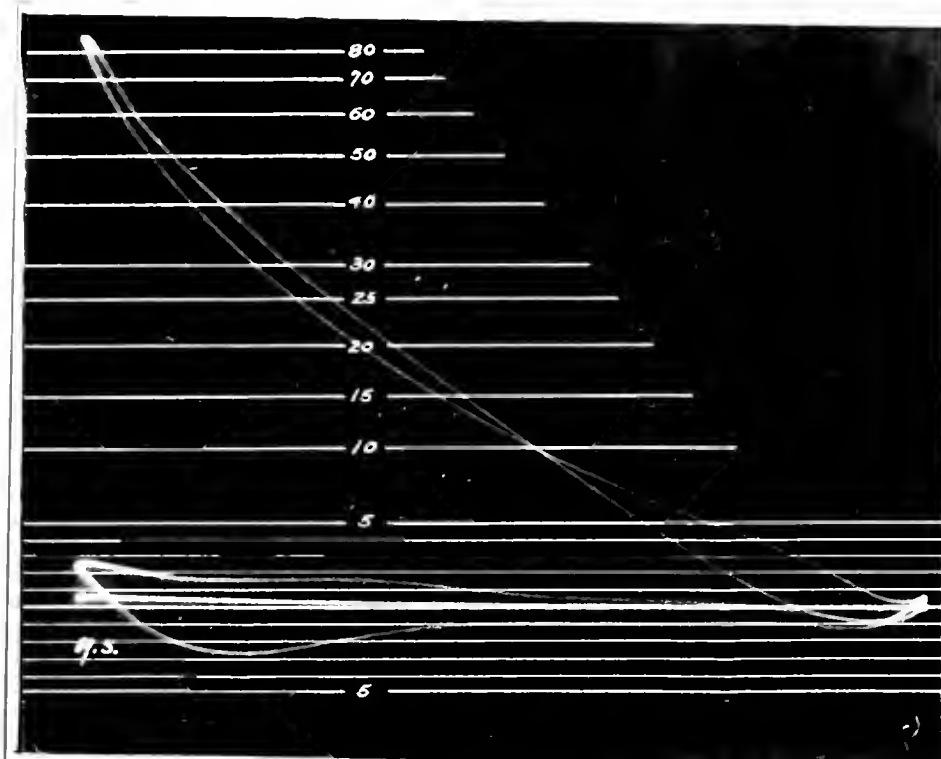


Card No. 11 .

Card No. 12 .

Air card	Disk "A".
Speed	508 R.P.M.
Throttle	Wide open.

In taking this card the engine was driven by the dynamometer. The card shows a compression pressure of 82 lbs. per sq. inch.

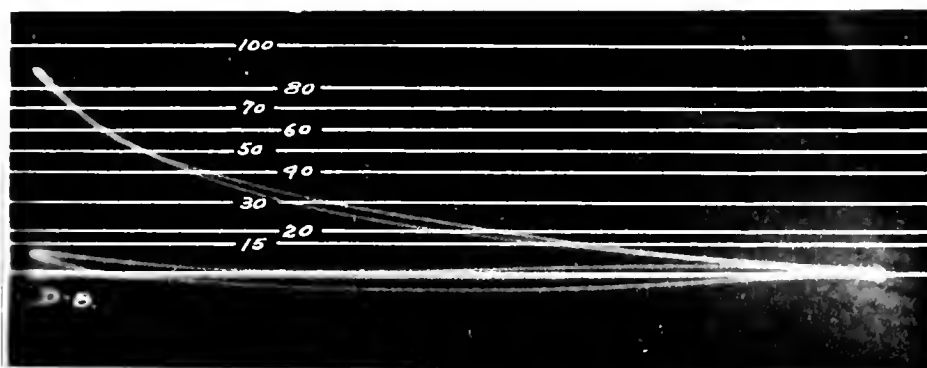


Card No. 12 .

Card No. 13 .

Air card	Disk "B".
Speed	998 R.P.M.
Throttle	Wide open.

In taking this card the engine was driven by the dynamometer. The card shows a compression pressure of 90 lbs. per sq. inch.



Card No. 13 .

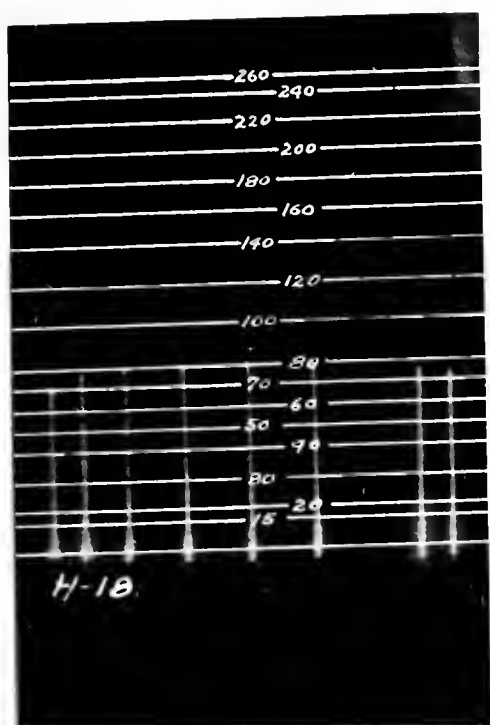
Card No. 14 .

Compression Pressures at Different
Speeds.

Data.

Line	Speed	Pressure.
1	300	70
2	500	76
3	700	79
4	800	80
5	900	80
6	1000	80
7	1100	75
8	1200	73

In obtaining this data,
the engine was driven by the dynamometer.
It was not possible to drive the engine
at speeds higher than 1200 R.P.M. because
of the circuit breaker flying out.



Card No. 14 .

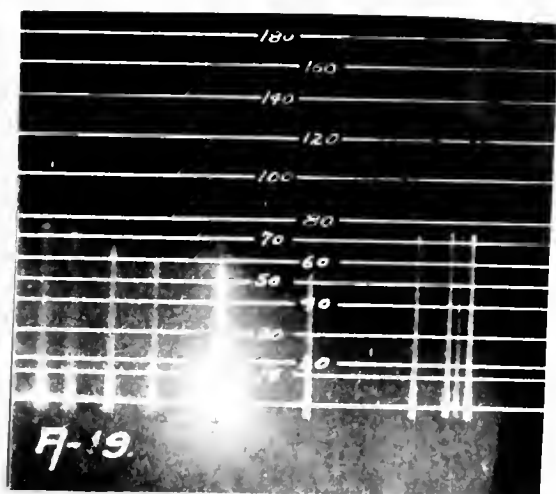
Card No. 15 .

Compression Pressures at Different
Speeds.

Data.

Line	Speed	Pressure.
1	1000	75
2	1100	70
3	1200	64
4	1300	60
5	1400	57
6	1500	53
7	900	73
8	800	74
9	700	74
10	600	74

In obtaining this data,
the engine was run on three cylinders,
the fourth being the one whose pressures
were taken. This gives the compression
pressure when using a rich gasoline mixture,
the throttle being wide open.



Card No. 15 .



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